RUAG

Aerospace Defence Technology

Center Aerodynamics – Newsletter 13 – Fall 2006

In this Edition

Dear reader,
I am proud to present you the second newsletter of 2006. The main focus of the present issue lies on the experimental and theoretical methods which are used to determine the effect of the ground on the aerodynamics of an airplane. This effect is very important during take-off and landing and has to be considered during the development of an airplane.
A basic study of ground effect for UAVs using our state of the art computational fluid dynamics (CFD) solver NSMB showed excellent results compared to wind tunnel tests.
On the experimental side, wind tunnel tests in the Large Wind Tunnel Emmen (LWTE) have been performed with the Airbus A400M model. The powered tests were very challenging, but successful.
Other recent activities, which are shortly described, include a new video system introduced in the LWTE. This system has considerably improved our capabilities for soiling tests and flow visualization with tufts.
The Center Aerodynamics is also a specialist for custom-made test setups. This is illustrated by the test rig designed to help in the development of the Laser Interferometer Space Antenna (LISA). LISA will be placed on a satellite for detection of gravitational waves in space.
A new section introduced in this newsletter is a list of publications and presentations made by members of the Center Aerodynamics. The references show our strong commitment to innovative technology in the fields of aerodynamics and instrumentation.

I hope you will enjoy reading this newsletter. Please feel free to contact us if you would like to get additional information.

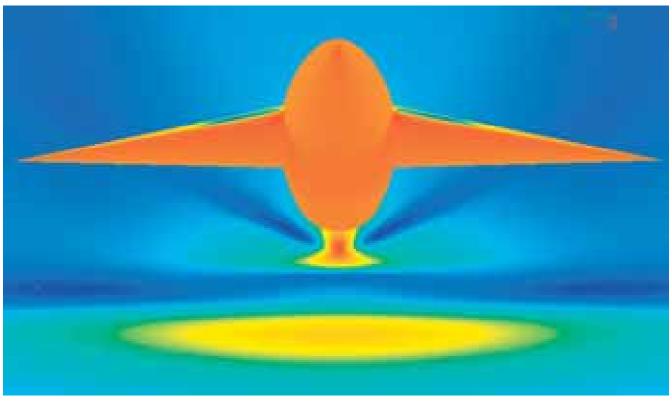
Michel Guillaume
Head Center Aerodynamics

The Simulation of Ground Effect

During take-off and landing, the wingtip vortex cannot fully develop due to the vicinity of the ground and an air cushion forms between the aircraft and the ground. The addition of these two effects modifies the aerodynamic characteristics of the aircraft by increasing the lift and is known as ground effect. The ground effect is most tangible at an altitude lower than one chord length of the wing and causes the aircraft to slightly glide over the runway. This sudden change of the flight behavior in the close vicinity of the ground has to be known precisely to prevent any risk of crash. Ground effect is studied at RUAG Aerospace with two different methods; numerical simulation and experimentally with a model and a special floor in the wind tunnel.

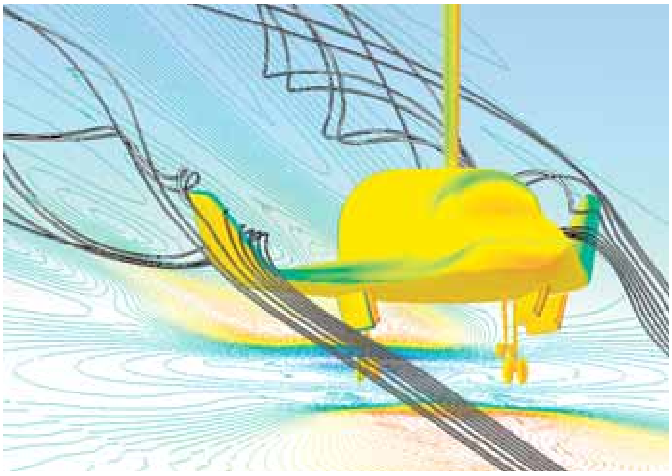
Numerical Simulation of Ground Effect

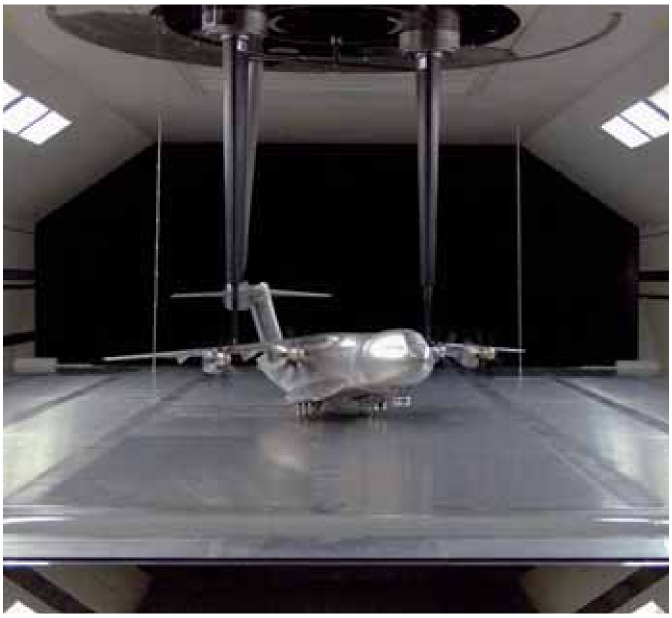
As part of the development of new UAVs, RUAG Aerospace investigated together with CFS Engineering, its partner and CFD specialist, the ground effect for a generic delta wing (NACA TN 4044) and the ESA Hermes reentry vehicle. CFD calculations were performed by CFS Engineering using their in-house flow solver NSMB (Navier-Stokes Multi Block). In both cases, experimental data for comparison with the CFD results were available. The NACA TN 4044 shape was chosen for its absence of vertical tail, which is a common design feature on UCAVs. In the case of the Hermes vehicle, wind tunnel tests were conducted in side slip flight conditions to simulate critical landings or take-offs with crosswind.



For the NACA TN 4044 wing at Mach 0.25, the angle of attack ranged from 6 to 20 degrees and the height over the ground varied from almost zero to altitudes where the ground effect is negligible. The deflection of the flaps was also simulated. The CFD computations were able to reproduce very accurately the increase in lift and decrease in drag measured in the wind tunnel as the distance to the ground decreases. Moreover the overpressure pattern on the ground due to the air cushion was also captured correctly by the numerical simulations.

For the Hermes vehicle, CFD results were compared with experiments performed in the RUAG Aerospace Large Wind Tunnel (LWTE). The simulations and the tests were both conducted at Mach 0.14 to reproduce low-speed landing conditions. Unlike the NACA TN 4044 wing, the Hermes vehicle has vertical stabilizers at the tip of the wings and a blunt tail causing a large detached flow. The angles of attack investigated ranged from 5 to 15 degrees and different heights over the ground were again investigated. Side slip angles up to 5 degrees were also imposed. Also in this case the drag and lift coefficients of the CFD simulations compared very well with experimental data. For the side slip flight conditions, the CFD simulations predicted correctly the rolling and yawing moments.





Ground Effect Testing in the Wind Tunnel

Ground effect tests in wind tunnels present their own very special challenges. The influence of the ground on the aerodynamics of the airplane must be simulated as accurately as possible. The ideal setup consists of a moving belt running at the same speed as the wind tunnel. This solution, which is standard in automotive wind tunnels, allows to correctly reproduce the relative movement of the airplane over the ground. Due to the complexity and the costs involved, only very few aerospace wind tunnels are equipped with such a moving floor. Therefore alternative means have to be found. The use of the wind tunnel floor as a ground plane is often a poor choice because the thickness of the boundary layer is excessive. The preferred solution consists of an additional intermediated floor which is mounted in the tunnel below the model. Special care is taken to have a smooth surface to keep the boundary layer small. This is also the chosen solution for ground effect testing in LWTE.

The ground effect floor spans the width of the tunnel and is 9 meters long. The vertical position of the floor can be varied to simulate different heights of the aircraft over the ground. At the trailing edge of the floor, two flaps can be deflected so that a homogeneous velocity distribution is obtained in the test section independently of the blockage due to the model. This is controlled by equalizing the pressure between the top and the bottom of the floor, as measured by pressure taps at the leading edge of the floor. Specific ‘empty’ wind tunnel (without the model but with the floor installed) calibrations are performed at the different floor heights of interest.

The setup can be used together with all the main model mounting configurations available in the LWTE: mono-strut, 3-strut and rear sting. For recent tests with the powered model of the Airbus A400M the 3-strut configuration was used. The wind tunnel tests were completed to the customer’s entire satisfaction.

With the successful numerical and experimental investigation of ground effect, RUAG Aerospace and CFS Engineering have demonstrated their capabilities for the accurate prediction of ground effect and are ready for the next milestones in the development of future generation aircraft and UAVs.

Recent Activities

New Video System in the LWTE

Flow visualizations are an important tool for the aerodynamicist to help him understand the flow around his test object. Depending on the application visualizations are performed using smoke, tufts or liquids. The results are documented either by video or photography. Since January 2006, the LWTE is equipped with a new video system with increased capabilites and flexibility. New features include the simultaneous recording of two independent sequences obtained from the mixing of up to six video input channels and, the possibility to superpose wind tunnel data (model angle of attack, wind tunnel speed, etc.) as well as text input. The cameras can be remotely controlled with a joystick (orientation and zoom). A simple user interface makes it possible for the customer to supervise and perform the recordings by himself.

The RUAG test engineer also benefits from this new video system, with a dedicated operating screen where up to sixteen images can be displayed, allowing him to keep an eye on different elements in and around the wind tunnel.

The new system was well received by our automotive and aerospace customers who have used it on many occasions since its introduction.

A New Tool for understanding Black Holes in Space

LISA (Laser Interferometer Space Antenna) is a joint project of ESA and NASA for detecting gravitational waves, the last point of Einstein's general relativity theory not yet verified by experiment. The idea is to release dense cubical masses inside three distant satellites to float freely in the zero-g space environment. The movements of these masses are monitored with extreme accuracy and compared (correlated) with each other. Gravitational waves originating in massive stellar events like collapsing black holes should be detected by this setup when they run through space with the velocity of light. The accurate holding and impulseless uncaging of these masses is an important point which has to be tested in advance.

A laboratory test setup has been engineered and built by RUAG. The zero-g environment is simulated with four buoyancy balls keeping the central mass floating in a nearly neutral equilibrium. Two grabbing tips on both sides of the test mass are linearly actuated by stepping motors for caging and releasing the mass. A two-dimensional highly sensitive optical angular measuring device checks the mass orientation after caging.

Publications and Presentations

- M. Guillaume, "Calculations of F/A-18 Fatigue Loads and Wing Deformation using Computational Fluid Dynamics", 25th International Congress of the Aeronautical Sciences (ICAS), September 3-8 2006, Hamburg, Germany.
- P. Aschwanden, U. Knörnschild, J. Müller, "Experimental Study on the Influence of Model Motion on the Aerodynamic Performance of a Race Car", SAE 2006 World Congress, Vehicle Aerodynamics (2006-01-803, SP-1991), April 3-6 2006, Detroit, USA.
- M. Hasler, D. Herzberg, R.Hodel, "Systemablösung im Windkanal; Synchrone Steuerung von nichtlinearen Achsen mit LabVIEW Real-Time und PXI", Virtuelle Instrumente in der Praxis, Begleitband zum Kongress, VIP 2006, Rahman Jamal, Hans Jschinski (Hrsg.).

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